# City of Boulder
# Flood Warning and Response Planning

**Prepared by**

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**Flood Warning and Response**

**Introduction and Perspective**

The City of Boulder, Colorado has been identified as having one of the largest potentials for loss of life to flash flooding within Colorado. The source of the flooding and flash flooding is both long duration general rains during periods of rapid snowmelt in spring and high intensity, short duration thunderstorm rainfalls during the summer. **Table 1** below identifies some of the more important flooding events on both Boulder and South Boulder Creeks

**Table 1** Causes of historic flooding in Boulder/South Boulder Creeks

| **Boulder Creek** | |
|---|---|
| ***Date of the flooding event*** | ***Cause of the flooding event*** |
| May 21-23, 1876 | General rains and snowmelt |
| May 29-June 2, 1894 | 4.5-6" rain and rapid snowmelt. Slow flooding |
| June 1-2, 1914 | Heavy general rains and snowmelt runoff |
| June 2-7, 1921 | June 6 was peak day with > 3.00" of rain |
| May 4-8, 1969 | 5 day general rain, 8-10"+ and snowmelt |
| **South Boulder Creek** | |
| May 29-June2, 1894 | 4.5-6" rain and rapid snowmelt. Slow flooding |
| August 31-September 4, 1938 | Monsoon t-storms with 4-6" rain in < 6 hours |
| May 6-8, 1969 | 5 day general rain, 8-10"+ and snowmelt |
| *Note: additional flooding may have occurred* | *Records are scarce* |

Note that most of the flooding events are caused by a combination of long duration, general spring rains with the added problem of runoff enhancement by rapid melting of winter snow pack in the foothills to the west of Boulder. In each of these cases, the onset of flooding occurred gradually and loss of life was relatively low. The exception to this observation is the thunderstorm flash flood of September 2, 1938 that was produced by 4-6 inches of rain on South Boulder Creek. An added impetus to the flash flooding problem was noted immediately after the deadly Big Thompson Flash Flood of July 31-August 1, 1976 that killed 144 people in a foothills canyon barely 30 miles to the north of Boulder.

In direct response to the vulnerability of Boulder to a similar mountain flash flood, a panel of local experts developed an extensive flood detection network in the foothills to the west of Boulder, a flood warning plan and participated with Urban Drainage & Flood Control District of Denver, Colorado to develop a flash flood prediction program (F2P2) to augment National Weather Service flood predictions. **Figure 1** shows both the location of stream gauges, rain gauges and weather stations in this flood detection network. A listing of the active stations is found in Appendix A. Note that almost 90 percent of the gauges and stations in this network are located in the foothills to the west of Boulder. Only six rain gauges are located in on the plains.

This focus on a western source of flooding was given a rude awakening on July 28, 1997 when the City of Fort Collins, 45 miles to the north, experienced a 10-14 inch thunderstorm flash flood that killed 5 people in and along Spring Creek. Over 85 percent of the rainfall fell at elevations below 6,000 feet into a basin that had few, if any, flood detection devices. The event occurred in a city that had received awards for its planning and diligent efforts to reduce the flood threat to life and property. Please note that the rainfall associated with this event was well above the 100-year return frequency and probably could not have been planned for any better at the time.

Since the flood, Fort Collins has developed an enhanced flood detection network, an operational flood plain inundation mapping capability and a flood warning response plan that ties all the loose ends of operations, communications and response into a coherent effort. ***The question should be asked: is the City of Boulder ready for a Fort Collins type flash flood?***

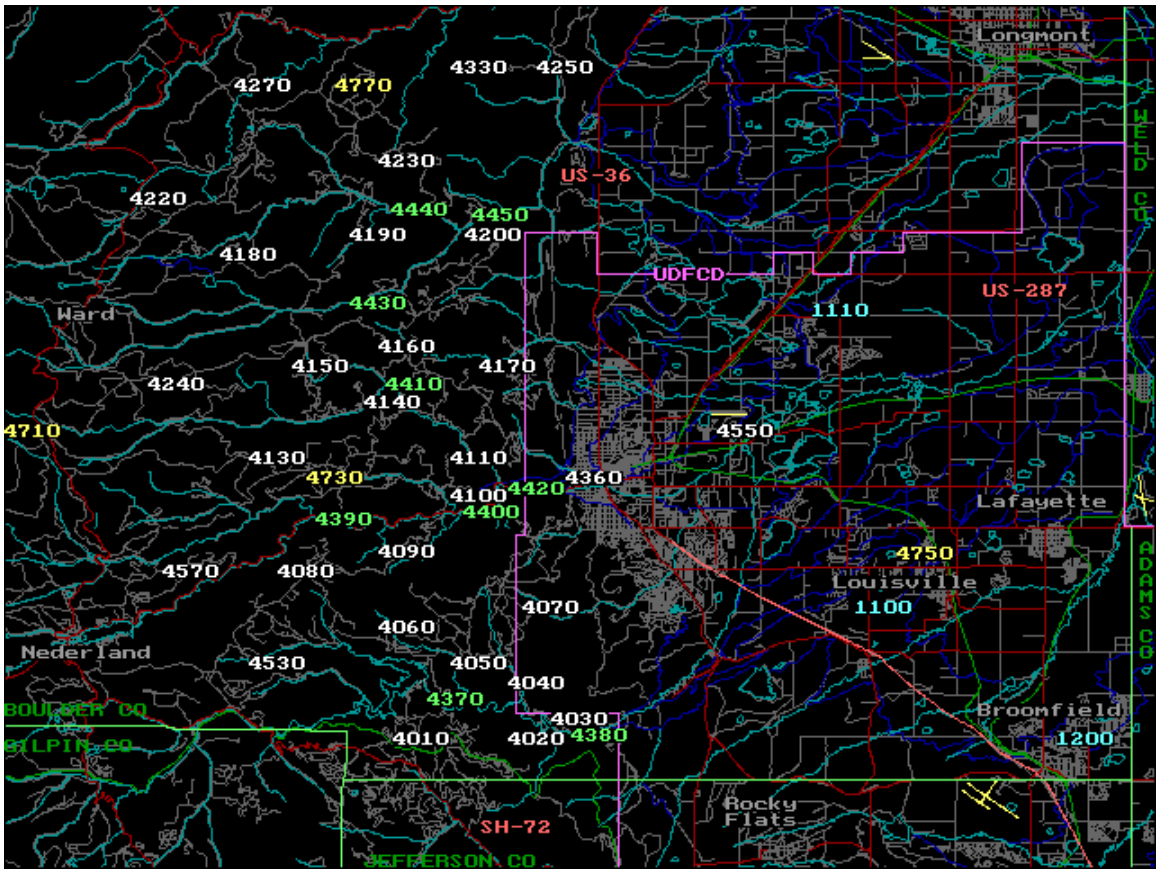


Figure 1 City of Boulder Flood detection Network and major stream locations

In response to this question the rainfall pattern associated with the Fort Collins 1997 flash flood was simply transposed over the lower urban basins of Four Mile Creek (Figure 2) and Bear Creek (Figure 3). If these events occurred today, would the City of Boulder be ready? Perhaps, the existing system and dedicated actions of the local emergency response community would result in a resounding YES. But questions still linger that were also present in Fort Collins immediately after their flood. Do we have a flood detection network in place that can assist in making evacuation decisions? Do flood warning response plans exist that link the prediction, detection, communications and response activities effectively? Would evacuation plans work? Does vulnerability that can be addressed and decreased through pro-active planning?

Perhaps in answer to these questions the City of Boulder – Utilities Division developed a scope of work for the development of future flood warning response plans and enhancements of the existing flood warning system as described in the Comprehensive Drainage Utility Master Plan (CDUMP). The project has developed an approach to consider future flood warning systems in the City of Boulder, Colorado based on the latest technology, weather forecasting and emergency response gudielines. The approach and recommendations were made at the “master plan” level contemplating more detailed analysis later.

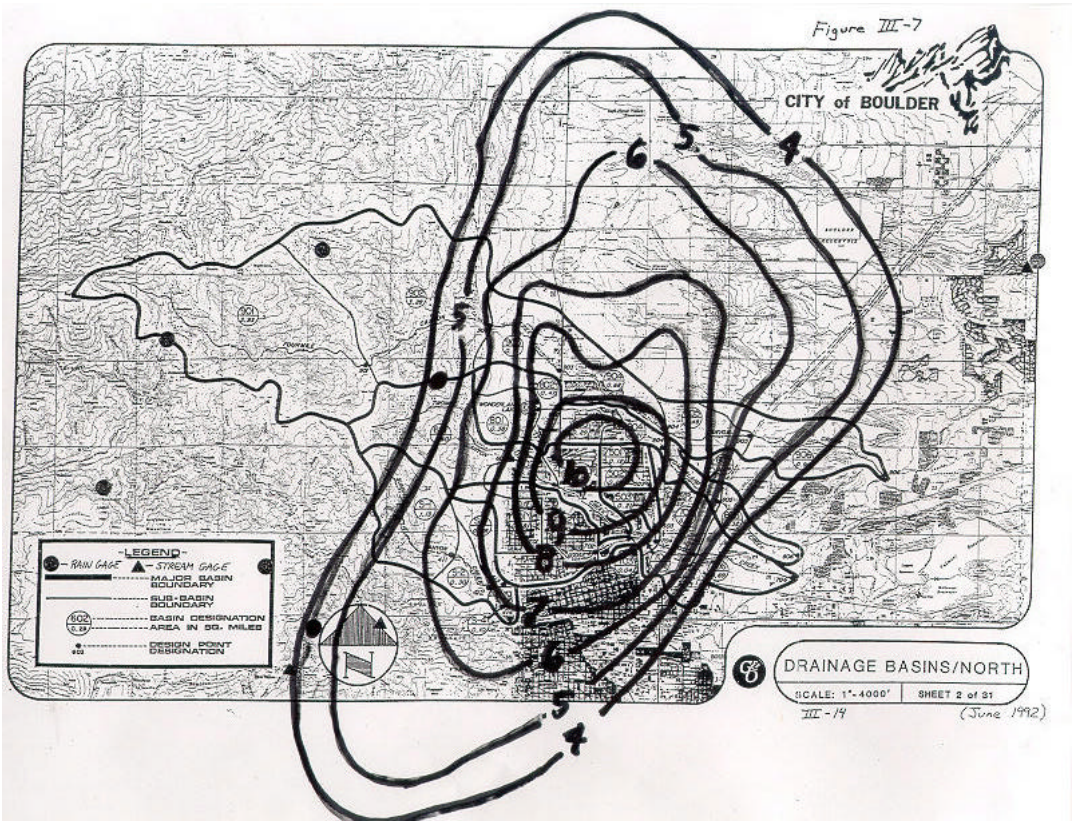


**Figure 2 Transposition of Fort Collins 1997 flash flood over the Four mile Creek lower urban basins**

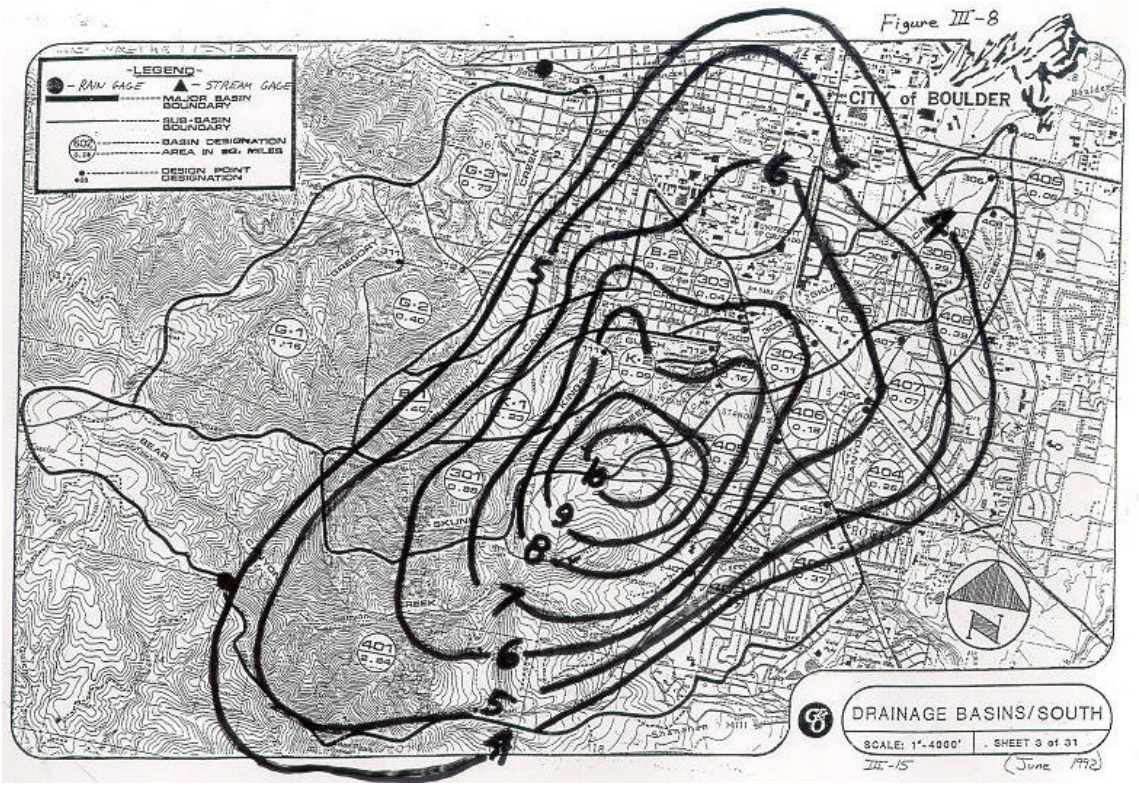

**Figure 3 Transposition of Fort Collins 1997 flash flood over Bear Creek lower urban basins**

**Project Scope**

The project developed tasks and a specific scope at a meeting held in Boulder between John Henz of HDR and Bob Harberg, Utilities Project Coordinator. The following three tasks were requested:

1. Develop a scope of work describing the needed enhancements to the existing flood detection networks and response plans on Boulder Creek, South Boulder Creek and Four Mile Creek and their tributaries.

2. Prepare a schedule of work for each basin that matches City of Boulder and Boulder County planning needs.

3. Prepare a cost estimate for each component.

4. Prepare a report that summarizes the above.

**Interviews and development of a flood warning response plan scope of work**

Interviews were held with Ned Williams, Assistant Director of Public Works for Utilities, Allan Taylor, Flood Management Program Coordinator and Bob Harberg, Utilities Project Coordinator to identify a scope of work that would meet the city's needs. The following areas of action were noted: enhancement of the existing flood detection system, develop flood warning response plans that link warning, communication, response and evacuation in a simple-to-use electronic plan format and emphasis on the ability to respond to a Fort Collins type of storm.

In addition to these interviews the City web pages were researched to identify structural flood activities and master plans under way. Master plan activities on Bear Creek, Wonderland Creek, Goose Creek, South Boulder Creek and Four Mile Creek were read and considered in the scope. Additionally the timing of activities on these creeks and potential threat of loss of life in the interims was considered.

The following five response plans were reviewed for added enhancements that could be developed:

1. **City of Boulder Incident Command System "BICS" Operation Manual, Section FP**

2. **City of Boulder Emergency Operations Plan**

3. **Boulder County Emergency Operations Plan**

4. **University of Colorado Flood Disaster Plan**

5. **Urban Drainage & Flood Control District Boulder Creek Flood Warning Plan**

The next section describes the project approach and scope of work for the development of enhanced flood warning response plans in each of the basins including Boulder Creek. The approach and scope of work is then augmented by a series of specific tasks that serve to identify system weaknesses and address then through workshop interactions by the affected response agencies. A general budget is then proposed that will address the needs of the specific basins of interest to the City of Boulder.

**Project Approach and Scope of work for Basin Flood Warning Response Plans**

The basic approach is to form a partnership with the city, county, Urban Drainage & Flood Control District and associated communities that maximizes available resources, identifies additional enhancements and provides a functional flood warning response plan which relates to the specific response needs and the response characteristics of the basins. While this approach may sound simple, it is based on several sound steps that embody the application of good science and common sense.

***Flood Warning Resource Inventory and Project Description***

1. Identify historical flooding events that have affected the county and the related weather factors involved.

2. Prepare an initial inventory of existing departments, agencies, and response organizations within the county and its cities involved in flood warning or response activities. Utilize existing flood warning response or all hazard response plans.

3. Identify each community agency's flood response policies and activities and their relationship to related agency activities. Identify the basic information needs and exchanges, co-ordination and communications required by critical agencies to complete their responses through brief, on-site or phone interviews.

4. Identify the existing meteorological and hydrologic flood detection and prediction resources available to the county. This identification will be accomplished using a combination of limited on-site interviews, collection and review of the most current available resources.

5. Prepare an initial assessment of the needs and tasking germane to the development of a flood warning response plan that is reflective of the community's needs.

***Phase I: Resource, Communications and Response Inventory.***

***Task A: Inventory of existing agencies, detection and warning resources, and related communications involved in City and County flood warning activities.***

1. Conduct a project kick-off meeting to explain the goals, timetable, objectives, desired interviews and coordination necessary for a successful project. Link this meeting to initial interviews with county/city officials and agencies.

2. Identify historical flooding events and the sources of potential flooding events that have affected the county and the related predictive factors involved.

3. Prepare an inventory of existing departments, agencies, and response organizations within the county and its cities involved in flood warning or response activities. Conduct in-person interviews with these agencies that include but are not limited to county/city public works departments, county sheriff, local fire and police departments, emergency management offices, dispatch centers and amateur spotter groups.

4. Identify each agency's flood response policies and activities and their relationship to related agency activities. Identify the information needs and exchanges, co-ordination and communications required by each agency to complete its responses through on-site interviews.

5. Identify the existing meteorological and hydrologic flood detection and prediction resources available to the county. This identification will be accomplished using a combination of on-site interviews, collecting and reviewing the most current available resources. Insure that links exist to National Weather Service and its Emergency Managers Weather Information Network (EMWIN) and NOAA Weather Radio, US Geological Survey, Corps of Engineers, and other information sources crucial to flood detection and prediction. Identify enhanced flood detection network and prediction needs.

6. Identify the existing areas of flood vulnerability using existing flood plain mapping.

7. Prepare diagrams identifying the existing and desired communications links, co-ordination, response and information needs of the county flood response agencies.

8. Prepare an initial report identifying the results of the surveys and their application to the development of an enhanced flood warning response plan.

**Task B: Prepare and conduct a Flood Warning Response Plan Workshop**

1. Prepare a flood workshop based on the results of the interviews obtained in Task A and the related report. Develop a tabletop flood event exercise, which reflects both prior flood experiences and predicted experiences using the enhanced information obtained through interviews.

2. Share the results of the inventory with the interviewed agencies and identify needs and linkages needed in communication, co-ordination, information and response activities during periods of flooding potential or flooding.

3. Discuss pro-active response to flooding events and the desired role of each agency. Establish means of improving the existing "plan".

4. Conduct a tabletop exercise with the existing "plan" and compare it to the potential "improved plan" which evolved through the interview process.

***Phase II: Prepare draft enhanced Flood Warning Response Plan (FWRP) and present to agencies in workshop setting.***

**Task C: Using the input from the inventory, interviews, data collection and workshop and the identified flood warning system component actions draft a flood warning response plan**

1. **Flood Vulnerability**: Finalize with the identification of the specific portions of the county that are at risk from flooding from nuisance street flooding to recognized 100-year floodplains. Provide the estimate of the lead-times from the identification of flood threat to each of the identified flood vulnerable areas.

2. **Flood Prediction:** Identify the capability of the National Weather Service to issue timely flash flood watches and warnings and integrate their prediction process into the backbone of the flood prediction component. Insure that the availability of the NWS' Emergency Manager Weather Information Network's products and their integration into the prediction/warning process exists. Insure a two-way communication of information

between the county and the NWS exists and insure the NWS has access to needed weather and river observations to make the predictions. Establish an easy to use flood watch/warning protocol for use by county agencies that connect to county emergency response activities. Identify opportunities for enhanced flood prediction services.

3. **Flood Detection:** Identify the existing flood detection network resources and any upgrades that are needed. Include evaluation and recommendations for the utilization of rain gauges, stream gauges, radar, spotters and related lead-times from identification of flooding to evacuation.

4. **Communications:** Identify the appropriate methods, agencies, contacts; lines of communication and information exchange needed to insure response agencies can accomplish pro-active response actions. A text and/or visual representation of the communication paths will be developed. Reverse-911 capability will be addressed.

5. **Response:** develop an action-tree for use by recipients of information which may include but are not limited to crew dispatching, evacuation logistics and routing, sandbagging and other flood fighting methods, road closures, resource allocation and re-location. The action-tree will be a reflection of the activities identified by local officials during the interview, inventory and workshop activities of this project.

6. **Planning and exercise:** Evaluate the need for periodic review and exercising of the flood plan and the continued maintenance of the key components of the flood warning system.

7. **Post-Flood Actions:** Recommend post-flood actions, in general, which may include but are not limited to applications for recovery funding, criteria for re-occupation of flood structures, and After-Flood report, relations with news media and government assistance for flood victims.

8. **Prepare draft FRP:** Prepare a draft flood response plan using input from the agency inventory and the Flooding Response Workshop that embodies the seven action components to link activities of departments, coordination of response agencies, information from the flood detection network and prediction sources into a workable response plan.

9. **Conduct draft FRP workshop:** Review proposed draft plan with participating agencies through a Flood Warning Response Plan review workshop and "test" the new plan.

**Task D: Prepare final form of flood warning response plan and additional recommended upgrades**

1. Prepare the flood warning response plan in a format acceptable to the users specific needs. This format could be in a binder, a series of charts, an action sheet keyed to the level of flood potential or river observations, GIS-linked observations and modeling or other simple electronic format.

2. Identify the upgrades needed to the county flood detection network and the flood prediction information, connection to the NWS Emergency Manager Weather Information Network (EMWIN) and planned integration with county/city GIS services.

3. Submission of a final project report

***Phase III: Final Preparation and delivery of Flood Warning Response Plan (FWRP).***

*During this phase the comments solicited from the workshop and review action items are incorporated into the flood warning response plan. If implementation of an electronic form of the plan is required, time is taken to test the connectivity of the plan and utility for one final interaction before the plan is offered for acceptance. The delivery of the plan includes a training day for the response and action agencies involved with the plan that offers a "hands on" exercise and the opportunity for one-on-one interaction. If multiple presentations are needed plans can be made to adjust the budget according to the needs of the city.*

***Phase IV: Enhancements to Flood Warning Response Plan (FWRP).***

Phase IV identifies additional enhancements of the FRP that may be needed but are either beyond the scope of the project or the immediate financial resources of the communities. A plan for adding these enhancements and their benefits is provided.

The above outlined general approach has been used on several flood response plans in Arizona and Colorado with very successful results. It appears that this general approach is in concert with the proposed scope of services requested by City and county. The application of this approach in response to your community's needs should be easy to accomplish.

The county has developed a functional flood detection network. Display and application of the rainfall and stream flow data obtained from the detection network has been facilitated by the use of DIAD's StormWatch software. This software is recommended as a platform of choice due to its easel manipulated Access based database. However, existing city software and models will be considered for implementation if the city so desires.

The need to link this rain/stream flow data base to city/county GIS, a variety of HEC models, both a National Weather Service and optional basin-specific quantitative precipitation forecast (QPF) and NWS and vendor-based WSR-88D Doppler radar and radar-rainfall products to produce effective detection of flood potential and enact pro-active response activities is anticipated. Enhancements to the existing flood detection network will be relative to network gauge density and the addition of automated weather stations. Flood plain inundation modeling and modules that will fit directly into this plan are recommended. Budget for the flood plain inundation mapping has not been included in the scope of this plan but is recommended for both South Boulder Creek and Boulder Creek and their tributaries.

Table 3 provides a summary of the recommended flood warning and response enhancements including estimated costs.

## Table 3 - City of Boulder Flood Warning Response Plan Enhancements Summary Table

| Basin Name | Warning Rain G. UP/DN | Warning Stream G. UP/DN | Warning Sirens | Response Flood Plan | Total Estimated Costs |
|---|---|---|---|---|---|
| **Four Mile** | **0/1** | **0/1** | **1** | **X** | |
| Wonderland | | | | | |
| | | | | | |
| **Estimated Cost** | **$20,000** | | **$20,000** | **$50,000** | **$90,000** |
| **Goose Creek** | **0/1** | **0/1** | **0** | **X** | |
| Two Mile | | | | | |
| Elmer's Two Mile | | | | | |
| | | | | | |
| **Estimated Cost** | **$20,000** | | | **$50,000** | **$70,000** |
| **Boulder** | **0/3** | **0/1** | **0** | **X** | |
| Gregory | | | | | |
| Sunshine | | | | | |
| | | | | | |
| **Estimated Cost** | **$40,000** | | | **$50,000** | **$90,000** |
| **Bear Creek** | **0/3** | **0/0** | **0** | **X** | |
| Skunk | | | | | |
| Kings | | | | | |
| Blue Bell | | | | | |
| | | | | | |
| **Estimated Cost** | **$30,000** | | | **$50,000** | **$80,000** |
| **South Boulder Creek** | **2/3** | **0/1** | **1** | **X** | |
| Viele Channel | | | | | |
| Dry Creek No. 2 | | | | | |
| | | | | | |
| **Estimated Cost** | **$60,000** | | **$20,000** | **$50,000** | **$130,000** |
| **Total Estimated Cost** | **$170,000** | | **$40,000** | **$250,000** | **$460,000** |

RG = Rain Gauge SG = Stream Gauge UP = Upstream DN = Downstream

Warning Sirens are interactive warning tools for direct contact with the public by the city
Response Plans refer to enhanced flood warning response plans to connect pro-active agency response with warning